Nitrogen Fertilization of Canola and Wheat Grown on Fallow Fields

Fernando Selles[1] and Rigas E. Karamanos[2]
[1]Agriculture and Agri-Food Canada, Box 1030, Swift Current, SK S9H 3X2
[2]Western cooperative Fertilizers Limited, P.O. Box 2500, Calgary, AB T2P 2N1,
E-mail: re.karamanos@westcoag.com

Abstract

This is the second year of a three-year project to assess N fertilizer needs of canola and wheat grown on fallow fields. The project is being carried out at six sites (three in Saskatchewan and three in Alberta) utilizing a uniform protocol of six N rates (0, 20, 30 40 and 50 kg N ha^{-1} for wheat and 0, 15, 30, 45, 60 and 75 kg N ha^{-1}for canola) arranged in a randomized complete block design. Other nutrients are applied as per soil test requirements. Environmental conditions over the first two years covered the two extremes, i.e., dry in 2003 and wet in 2004. Although the magnitude of response was markedly different between the two years, a response was nevertheless was obtained in both instances with the application of 10 to 30 kg N ha^{-1} in the drier year and 50 to 75 kg N ha^{-1} in the wet year. Yield increases in both years were both agronomically and economically significant. Data from this project will be utilized to drawing a strategy for fertilizing crop grown on fallow fields based on agroecological and economic risks.

Introduction

The practice of summer fallowing was adopted in the drier areas of the prairies (Brown and Dark Brown Soil Zones) to conserve moisture, afford weed control, allow the soil to "rest", i.e., mineralize N, maintain stability of crop yields, manage trash and allow for better seedbed preparation and provide a more uniform work load. This practice, however, combined with cultivation encourages wind and water erosion, water percolation and leaching losses in lighter textured soils, spread of salinity and loss of organic matter and consequently mining of soil nutrients, such as nitrogen (N).

Early reports (Shutt, 1910) indicated that prairie soils of western Canada used to be of the richest of known soils in organic matter content (Table 1). Reports in the late 1930's and mid-1940's had already identified significant losses of organic matter due to cultivation (Table 2). Those losses ranged from 10 to 57% depending on soil texture.

Table 1. The amount of organic matter in prairie soils[1].

	Organic matter content		
	Mean	Maximum	Minimum
		(%)	
Manitoba	15.8	26.3	11.3
Saskatchewan	11.9	14.2	4.2
Alberta	11.9	17.6	4.5

[1]from Shutt (1910)

In a 1994 news release by the Saskatchewan Soil testing Laboratory (Grainews, January 1994), the average soil organic matter levels from 1993 soil tests were compared to 1945 soil organic matter levels (Table 3) and relatively losses of organic matter were derived.

Table 2. Losses of organic matter from prairie soils (0-30 cm) due to cultivation[1].

Soil Zone or soil type	Years of cultivation	%loss in organic matter content
Brown	16	16
Dark Brown	22	18
Black	26	15
Black Transition	24	22
Gray Transition	12	10
Gray	13	25
Dark Brown		
Haverhill loam	-	36
Hatton fine sandy loam	-	57
Hatton coarse sandy loam	-	21

[1]adapted from Caldwell et al. 1939; Newton et al. 1945.

Table 3. Changes in soil organic matter[1]

Soil Zone	1945	1993	% Loss
		(%)	
Brown	2.8	2.1	25
Dark Brown	4.2	2.8	33
Black	10.8	4.7	57
Black Transition	7.8	4.4	44

[1]SSTL News Release, Grainews/January 1994.

A consequence of these losses has been a dramatic reduction in mineralizable N in the Brown and Dark Brown soils that has impacted N fertility of crops grown on fallow soils.

Nitrogen recommendations for crops grown on fallow soils in Saskatchewan were originally based on soil testing ranges developed by the Saskatchewan Soil Testing Laboratory (SSTL). The last published ranges date to 1990 (SSTL 1990) and are summarized in Table 4. These rates were modified based on crop and fertilizer prices and the marginal return over marginal cost. Recommendations for both fallow and stubble crops were read off the same table.

Table 4. General Nitrogen Requirement Guidelines in Saskatchewan prior to 1991.

	Soil + Fertilizer Nitrogen					
Crop	Brown			Dark Brown		
	Dry	Normal	High Risk/Wet	Dry	Normal	High Risk/Wet
Wheat	45	60	85	60	75	100
Canola	50	65	90	70	85	110

A new system of N fertilizer recommendations was proposed by Henry (1990; 1991) and was adopted by the SSTL in 1991 under the acronym F.A.R.M. (Kruger et al. 1994). This system allowed for estimation of N immobilization and, thus, differentiation between recommendations for fallow and stubble crops. Hence, for the same soil test level recommendations a given crop grown on fallow would receive lower N recommendations than when grown on stubble that is proportional to immobilized N. In spite of this improvement, crops grown on fallow fields remain under-fertilized with N.

The objectives of this project are to determine yield, protein and/or oil response to N application, the soil and environmental factors that affect the probability of achieving the observed responses and the nitrogen use efficiency of the system at the fertilizer N rates used. This report, in particular, focuses on yield responses after two years of experimentation and assesses water use efficiency (WUE) values for wheat and canola that are integral to deriving yield targets. Nitrogen rates to obtain maximum yield in these experiments are contrasted to recommended rates derived the FARM system.

Materials and Methods

Six trials were established in 2003 at three locations in Saskatchewan and three in Alberta (Table 5). The South Farm, Bulin and Stewart Valley sites were sown on May 17, 21 and 22 in 2003 and 6, 8 and 18 in 2004, respectively whereas the Bassano, Hussar and Cheichen sites were sown on May 15, 23 and 23 in 2003 and May 6, 12 and 15 in 2004 , respectively. All sites were seeded to AC Superb and AC Eatonia and liberty link tolerant cultivars Invigor 2573 and 2733 in 2003 and 2004, respectively.

Table 5. Site characteristics of the four trials.

	Year	Organic matter	Texture	pH	NO_3-N	P	K	SO_4-S
		(%)				lb/acre		
Bulin[1]	2003	2.0	Sandy Loam	6.8	22	18	321	15
	2004	2.0	Sandy Loam	6.8	19	8	265	21
Stewart Valley	2003	3.2	Heavy Clay	7.5	67	8	365	1611
	2004	3.2	Heavy Clay	7.5	52	8	563	446
South farm	2003	3.3	Silt Loam	6.5	37	18	371	20
	2004	3.3	Silt Loam	6.5	45	14	489	28
Hussar[2]	2003	1.1	Clay	7.8	35	27	1094	22
	2004	3.2	Clay	8.1	34	12	742	86
Bassano	2003	2.2	Loam	7.9	50	18	510	30
	2004	2.4	Loam	7.6	40	16	530	24
Gleichen	2003	3.0	Clay Loam	8.1	26	38	1040	88
	2004	3.1	Clay Loam	7.7	39	42	916	88

[1]Saskatchewan sites: NO_3-N and SO_4-S in 0-24 inch depth P and K in 0-6 inch depth.
[2]Alberta sites: NO_3-N and SO_4-S in 0-12 inch depth P and K in 0-6 inch depth.

The experimental design included six N fertilization treatments as follows: 0, 10, 20, 30, 40 and 50 kg N ha^{-1} for wheat and 0, 15, 30, 45, 60 and 75 kg N ha^{-1} for canola. Nitrogen treatments were side banded. All trials received a blanket application of seed-placed P_2O_5 as triple super phosphate (0-45-0) at a rate of 30 kg ha^{-1}, and K_2O and S as potassium sulphate (0-0-51-17) at a rate of 51 and 17 kg ha^{-1}, respectively. All treatments were replicated four times.

A tipping bucket rain gauge was installed at each of the four sites to record precipitation events during the growing season. Available soil moisture content was estimated at seeding and again at harvest time using a soil moisture probe and converting depth of moist soil to inches of available moisture based on soil texture in Alberta and through actual soil moisture measurement in the Saskatchewan sites. The plots were harvested using a Wintersteiger Nurserymaster Elite experimental combine and the grain samples were dried at 60 °C by forced air and weighed to determine grain yield.

The results from all tests were subject to ANOVA and regression analysis using SYSTAT 8.0 (SPSS Inc. 1998).

Results and Discussion

Two of the canola sites in Alberta were lost in 2003 due to the heavy infestation with flea beetles. Available soil moisture and growing season precipitation at all experimental sites are shown in Table 6. Although soil moisture supplies in both years were exceptional (except in South Farm in 2004), 2003 was characterized with lower than average pgrowing season precipitation and 2004 with average or above average precipitation.

Table 6 Spring soil moisture and growing season precipitation at the experimental sites.

Site	Year	Soil moisture	Precipitation[1] M, J, J	Precipitation[1] M, J, J, A	Nearest Probability[2] M-J	Nearest Probability[2] M-A
				(inches)		
Bassano	2003	5.30	3.90	5.10	75	50
	2004	6.50	5.16	5.91	50	50
Gleichen	2003	5.50	4.80	6.40	75	50
	2004	7.20	6.40	9.00	50	25
Hussar	2003	5.60	1.95	5.70	75	50
	2004	6.50	5.70	8.95	50	25
Bulin	2003	5.94	1.63	3.15	75	75
	2004	4.52	5.70	8.95	50	25
South Farm	2003	4.05	3.46	5.83	75	50
	2004	2.83	9.10	12.58	25	25
Stewart Valley	2003	10.41	2.27	2.49	75	75
	2004	8.02	4.43	8.02	50	25

[1] M, J, J = May, June, July; M, J, J, A = May, June, July, August.

[2] Nearest probability alludes to the probability of precipitation over the May-July (M-J) or May-August (M-A) rounded off to the nearest 25% (i.e., 25, 50 and 75% probability).

Potential grain yields for both wheat and canola reflected moisture conditions and soil N fertility. Average yield increases in 2003 were in the order of 270 kg ha^{-1} (4 bu/acre) for wheat and 220 kg ha^{-1} (4 bu/acre) for canola (Fig. 1a, b), which corresponded to 13 and 31 % yield increases, respectively. In 2004, average grain yield increases were far greater, 740 and 1230 kg ha^{-1} or 11 and 22 bu/acre for wheat and canola, respectively (Fig. 2 a, b). Crops grown on soils with greater residual N required less fertilizer N to obtain maximum yield (Tables 7 and 8). Under dry conditions soil + fertilizer N at which maximum response was obtained was in the range of 70 - 75 kg N ha^{-1}, whereas under above normal moisture conditions in the range of 95-105 kg N ha^{-1}. It would appear that grain yields at the Boulin site never reached maximum with the rates used.

(a) **(b)**

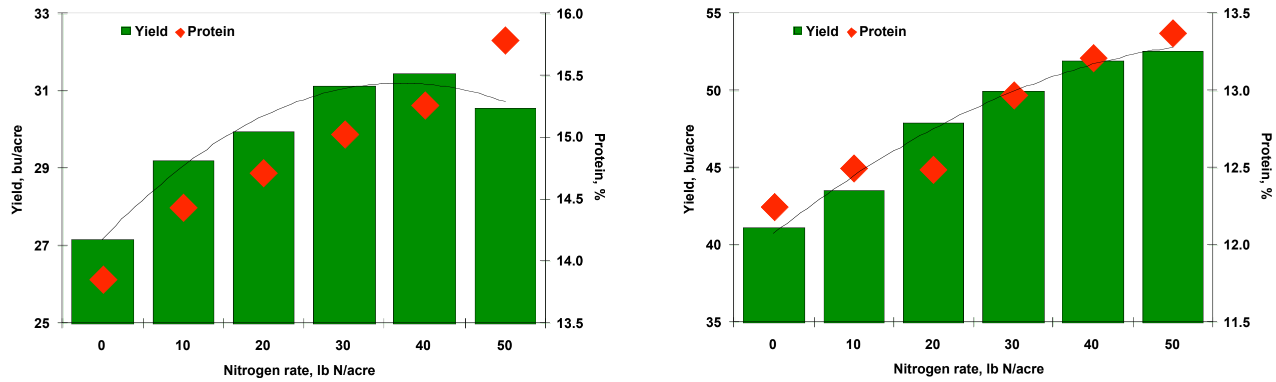

Figure 1. Wheat grain yield and protein response to N fertilizer rates in 2003 (a) and 2004 (b).

(a) **(b)**

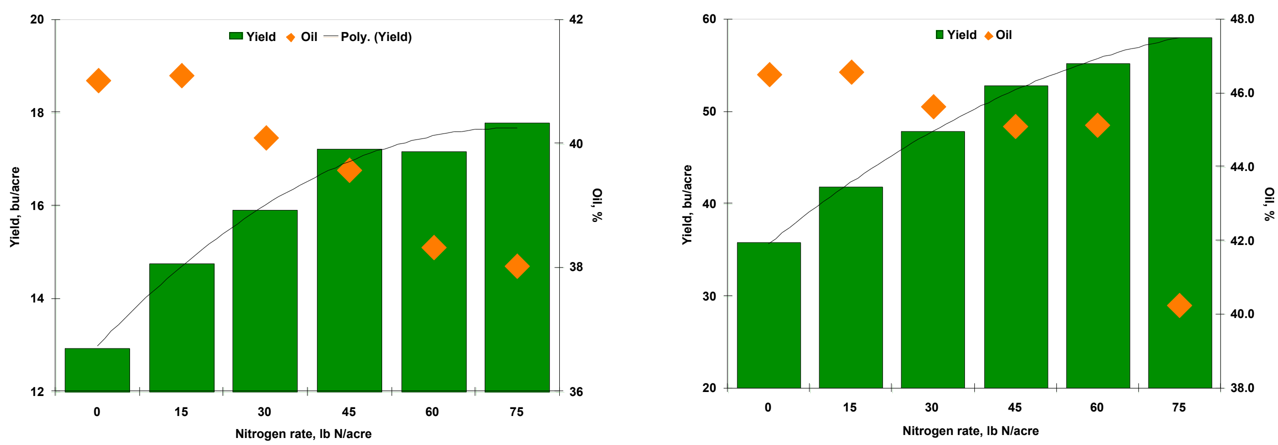

Figure 2. Canola grain yield and protein response to N fertilizer rates in 2003 (a) and 2004 (b).

Table 7. Control yields and maximum yield increases of wheat grain with the corresponding rates of N.

Site	Control yield		Rate	Yield increase		Control yield		Rate	Yield increase	
	kg ha^{-1}	bu/ac	kg ha^{-1}		bu/ac	kg ha^{-1}	bu/ac	kg ha^{-1}		bu/ac
Hussar	1743	25.9	0	0	0.0	3454	51.4	0	0	0.0
Bassano	1688	25.1	40	453	6.7	2755	41.0	20	606	9.0
Gleichen	2133	31.7	40	659	9.8	3663	54.5	40	965	14.4
Bulin	982	14.6	10	315	4.7	1127	16.8	50	1515	22.5
South Farm	1957	29.1	0	0	0.0	2798	41.6	40	696	10.4
Stewart Valley	2456	36.6	10	129	1.9	2791	41.5	50	745	11.1

Protein levels increased with N fertilization and were much greater under drier conditions (Fig. 1). Higher protein levels in canola led to a corresponding decrease in oil content (Fig. 2).

Table 8. Control yields and maximum yield increases of canola grain with the corresponding rates of N.

Site	Control yield		Rate	Yield increase		Control yield		Rate	Yield increase	
	kg ha^{-1}	bu/ac	kg ha^{-1}		bu/ac	kg ha^{-1}	bu/ac	kg ha^{-1}		bu/ac
Hussar			--			2091	37.3	75	1512	27.0
Bassano	738	13.2	45	530	9.5	2212	39.5	75	1127	20.1
Gleichen			--			2383	42.6	75	2350	42.0
Bulin	279	5.0	10	148	2.6	811	14.5	60	1551	27.7
South Farm	757	13.5	0	0	0.0	2536	45.3	45	606	10.8
Stewart Valley	866	15.5	10	123	2.2	1989	35.5	45	647	11.5

Henry et al. (2000) and Karamanos et al. (2001) introduced the used of Nitrogen Fertilizer Recommendation Zones (NFRZ) as a means of improving N recommendations for prairie soils. In conjunction with the development of NFRZ Henry (2000, personal communication) proposed the use of water use efficiency (WUE) values for crops that depend on probability of precipitation. This contrasts the original system proposed by Henry (1990) in which a unique WUE value was assigned to each Soil Climatic Zone (SCZ). The WUE values for Brown and Bark Drown SCZ and the Palliser Plain NFRZ are contrasted in Table 9. The relationship between measured WUE values and those in the Henry (2000) version was significantly better than between measured WUE values and the Henry (1990) version (Table 10).

Table 9.Comparison between water use efficiency (WUE) values for wheat and canola (bu/acre) in the original and modified system of recommendations.

		Probability of precipitation		
SCZ/NFRZ	Version	75%	50%	25%
		Wheat		
Brown	1991	3.75	3.75	3.75
Dark Brown	1991	4	4	4
Palliser Plain	2000	3.5	4	4.5
		Canola		
Brown	1991	2.9	2.9	2.9
Dark Brown	1991	3.1	3.1	3.1
Palliser Plain	2000	2.75	3	3.25

Table 10. Relationship between measured and theoretical WUE values[1].

Period	Equation	r^2
	Wheat	
May-July	$WUE_{1991} = 3.06 + 0.2707WU - 0.0205WU^2$	0.201
	$WUE_{2000} = 3.46 - 0.208WU + 0.0608\,WU^2$	0.459
May-August	$WUE_{1991} = 3.32 + 0.169WU - 0.0068WU^2$	0.26
	$WUE_{2000} = 4.08 - 0.4486WU + 0.1001WU^2$	0.267
	Canola	
May-July	$WUE_{1991} = 2.88 + 0.020WU - 0.0002WU^2$	0.089
	$WUE_{2000} = 2.64 + 0.0276WU + 0.0073WU^2$	0.599
May-August	$WUE_{1991} = 3.01 - 0.0821WU + 0.0176WU^2$	0.298
	$WUE_{2000} = 2.29 + 0.296WU - 0.0229WU^2$	0.778

[1]WU = water use.

A closer relationship between observed and predicted WUE values for wheat when May, June and July precipitation was used, whereas for canola closer relationship was obtained when May, June, July and August precipitation was used. This points merits further investigation.

The relationship between predicted N recommended rates and rate of maximum yield in these experiments based on the pre 1991 (Table 4), post 1991 (Henry 1991) system of recommendations and a modification introduced by Western Cooperative Fertilizers Limited in 2005 to include an estimate of mineralizable N is shown in Table 11.

Table 11. Relationship between measured and theoretical WUE values[1].

Year	Equation	r^2
	Wheat	
2003	$Rate_{pre1991} = 5 + 0.75Rate_{max} - 0.0083Rate_{max}^2$	0.366
	$Rate_{post1991} = 5 + 1.1Rate_{max} - 0.02Rate_{max}^2$	0.335
	$Rate_{2005} = 4 + 1.65Rate_{max} - 0.0317Rate_{max}^2$	0.422
2004	$Rate_{pre1991} = 21.8 - 0.37Rate_{max} + 0.011Rate_{max}^2$	0.104
	$Rate_{post1991} = 20.8 - 1.50Rate_{max} + 0.039Rate_{max}^2$	0.612
	$Rate_{2005} = 25.7 - 1.90Rate_{max} + 0.0475Rate_{max}^2$	0.784
	Canola	
2003	$Rate_{pre1991} = 13.74 + 0.539Rate_{max}$	0.454
	$Rate_{post1991} = 7.41 + 0.406Rate_{max}$	0.467
	$Rate_{2005} = 16.32 + 0.595Rate_{max}$	0.433
2004	$Rate_{pre1991} = 402 - 13.17Rate_{max} + 0.115Rate_{max}^2$	0.736
	$Rate_{post1991} = 263 - 8.78Rate_{max} + 0.078Rate_{max}^2$	0.636
	$Rate_{2005} = 309 - 9.68Rate_{max} + 0.0848Rate_{max}^2$	0.693

Conclusion

Responses to N fertilization by crops grown on fallow fields can be significant even on drier years and reflect lower soil test N levels. It appears that we possess satisfactory tools for predicting and correcting N deficiencies.

References

Caldwell, A.C., Wyatt, F.A. and Newton, J.D. 1939. Effects of cultivation and cropping on the chemical composition of some western Canada prairie soils. Part II. Scientific Agriculture 23: 229-232.

Henry, J.L. 1990. Development of crop water production functions for wheat barley and canola to revise nitrogen fertilizer recommendations in Saskatchewan. Department of Soil Science, University of Saskatchewan, Saskatoon, SK, Mimeo Report.

Henry, J.L. 1991. Development of soil test based nitrogen fertilizer recommendations for wheat, barley, canola, flax and oats. Mimeo report, Department of Soil Science, University of Saskatchewan, Saskatoon, SK.

Henry, J.L., Shaykewich, C. and Karamanos, R.E. 2000. Nitrogen Fertilizer Recommendation Zones. AgroManager on Soils map. Western Co-operative Fertilizers Limited, Calgary, AB.

Karamanos, R.E., Shaykewich, C. and Henry, J.L. 2001. Nitrogen Fertilizer Recommendation Zones. Proceedings Soils and Crops 2001, February 22-23, University of Saskatchewan, Saskatoon.

Kruger, G.A., R.E. Karamanos and J.L. Henry, 1994. Fertility Analysis and Recommendations Manager (F.A.R.M.). Comm. Soil Sci. Plant Anal. 25, 955-965.

Newton, J.D., Wyatt, F.A. and Brown, A.L. 1945. Effects of cultivation and cropping on the chemical composition of some western Canada prairie soils. Part III. Scientific Agriculture 25: 718-737.

Saskatchewan Soil testing Laboratory. 1990. Nutrient requirement guidelines for field crops in Saskatchewan. SIP Mimeo Report, 33 pages.

SPSS Inc. 1998. SYSTAT 8.0. Chicago, IL.